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Plant Biology

How scientists light up their tobacco

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We have genetically engineered tobacco plants capable of producing their own light, a phenomenon never described in any plants in nature. In addition to its aesthetic potential, this could lead to significant advances in techniques for imaging and studying physiological processes in plants.

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The beauty of a night filled with glowing fireflies is possible through a process called bioluminescence, which allows a living organism to emit light using a chemical reaction. Among the known bioluminescent organisms are different bacteria, as well as fireflies, jellyfish, and certain mushrooms. Organisms can also emit light through fluorescence, wherein fluorescent compounds absorb light of a specific wavelength, and re-emit light of a longer wavelength. Plants contain a variety of pigments, which can fluoresce when exposed to external light. However, while plants form a diverse group of organisms, from majestic sequoias to tiny aquatic duckweed, we do not know of any bioluminescent plants.

In nature, bioluminescence serves a wide range of functions, from attracting prey or mates to warning off predators. In addition, both bioluminescence and fluorescence allow researchers to study molecular processes in living organisms, by measuring light emission. While using fluorescent labels is technically simpler, they are less sensitive, and work best in organisms with few native fluorescent compounds. Unfortunately, plants are full of such compounds, making bioluminescence an attractive alternative. However, getting all the necessary components inside plants in the first place remains a practical challenge, and as a result it’s not currently widely used.

The basic chemistry behind bioluminescence is simple: a small molecule, dubbed luciferin after the Latin word for “light-bringer”, is recognized and oxidized by an enzyme called luciferase, releasing light in the process. Different species have their own luciferin-luciferase pairs, and knowing the full genetic pathway behind their production is key to introducing autoluminescence into new organisms – the alternative is to supply luciferin externally, which can be expensive and technically challenging. However, until recently, only one bioluminescent system was fully genetically characterized, and its bacterial origin meant its compatibility with more complex organisms was limited. In particular, its application in plants was laborious, and light output was low.

We have now described a second bioluminescent system found in *Neonothopanus nambi*, a green-glowing mushroom. Fungi are closer to plants on the evolutionary tree than bacteria are, making this bioluminescent system more likely to be plant-compatible. This system produces luciferin by chemically modifying caffeic acid, a small metabolite which enjoys the good fortune of being ubiquitous not only in fungi, but also in plants. We reasoned that, by giving plants the fungal genes responsible for converting caffeic acid to luciferin, we could make plants that are capable of bioluminescence.

Spoiler: it worked.

For this experiment, we used tobacco, a long-time model organism in plant research which is both well-understood and easy to work with. In order to introduce the fungal genes into our plants, we used bacteria called Agrobacterium. Normally, Agrobacterium is a parasite which can inject its own DNA into plants and cause nutrient-rich tumours to form. For research purposes, a modified strain of Agrobacterium is used, in which its native tumor-inducing DNA is replaced with researchers’ genes of interest. Using this process, we inserted the fungal luminescence genes directly into the tobacco genome, literally seeing the results with our own eyes – since the light emitted by these transgenic plants was visible to the naked eye, albeit only in a dark room.

Interestingly, light emission was not uniform across time and space. Some parts of the plants, such as flowers, young roots, and injury sites glowed brighter, while aging leaves were dimmer. This broadly corresponded to known patterns of natural caffeic acid availability during different stages of growth and stress response, suggesting the bioluminescent system might be particularly well suited for studying these processes. We were also able to see waves of luminescence travelling rapidly through tissues, showing its potential for monitoring dynamic, time-sensitive molecular events. Importantly, transgenic plants were just as healthy overall as regular ones.

This project showed that autonomously glowing plants can become a reality. Future steps include optimizing the bioluminescent system to increase light output, and controlling the time and area of expression within the plant, making it easier to study specific questions about how plants work.

And of course, why stop at tobacco? Maybe one day we’ll be able to sit on the beach and read about the latest scientific discoveries by the self-sustained evening light of luminescent palm trees.